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INTRODUCTION

In planting an orchard, one of the first questions to be settled is the amount of space to be allotted to each tree for root and top development. This requires a decision as to how far apart the rows shall be and the distance between the trees in the rows. Aside from the number of trees that can be safely planted on an acre of ground, certain other practical considerations enter in, such as the best arrangement of the trees for convenience in cultivating, irrigating, brush burning, spraying and harvesting. A closely related problem is the question of what shall be done with orchards that are found to be too closely planted. In the first instance the planter strives to avoid a mistake, while in the second he tries to correct one. Both topics will be discussed in the succeeding pages.

The information on which this discussion is based was secured from an orchard planted on the University Farm at Davis for the purpose of studying planting distances, and from careful observations made in a number of established orchards in different parts of the state.

EXPERIMENTAL ORCHARD AT DAVIS

The experimental orchard at Davis was planted in February, 1915, and consisted of the following fruits: Royal apricots, Climax and Pond plums, Bartlett pears, Royal Ann cherries, Elberta peaches, and French prunes, the trees being arranged in blocks, with each block representing a different planting distance. The planting distances ranged from 12 x 12 feet to 36 x 36 feet, the number of trees per block varying from 302 in the former instance to only 33 in the latter. The total number of trees planted was 668, but as each block was provided with guard rows so that all trees used for record purposes were surrounded with other trees of their kind, only 354 remained on which to keep growth and yield data. Table 1 shows the number of trees in each block.

This orchard was valuable chiefly for studying the comparative growth of trees under various conditions of planting, ranging from

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TABLE 1

PLANTING PLAN AND NUMBER OF TREES OF EACH FRUIT PLANTED IN DIFFERENT BLOCKS

Planting distance and kind of fruit	Number of trees planted	Number used for record purposes	Planting distance and kind of fruit	Number of trees planted	Number used for record purposes
12x12 feet:			24x24 feet:		
Apricot	45	24	Apricot	12	6
Plum (Japanese)	25	12	Plum (Japanese)	6	2
Plum (European)	25	12	Plum (European)	9	4
Pear	45	24	Pear	12	6
Peach	36	24	Peach	12	6
Cherry	36	24	Cherry	15	6
Prune	40	24	Prune	12	6
16x16 feet:			30x30 feet:		
Apricot	24	15	Apricot	9	4
Plum (Japanese)	16	9	Plum (Japanese)	6	2
Plum (European)	12	6	Plum (European)	6	2
Pear	24	15	Pear	9	4
Peach	24	15	Peach	9	4
Cherry	28	15	Cherry	12	4
Prune	24	15	Prune	9	4
20x20 feet:			36x36 feet:		
Apricot	15	8	Apricot	9	4
Plum (Japanese)	9	4	Pear	12	4
Plum (European)	9	4	Cherry	9	4
Pear	15	8			
Peach	15	8			
Cherry	18	8			
Prune	15	8			

a badly crowded condition to the opposite extreme where they were so far apart that there could be little or no competition for moisture, soil nutrients, or light. Unfortunately, the plans made by the originator of the experiment did not provide for as many trees in the widely planted blocks as there should have been. Through the vicissitudes of subnormal rainfall and shortage of water for irrigation purposes during two or three seasons when the trees were coming into bearing, it became apparent that those in the crowded blocks in particular were being subjected to unusually severe conditions and that they were suffering accordingly. Radical thinning by taking out trees was resorted to, but the apricots and peaches did not recover their lost vigor. Even those having plenty of room showed continued signs of drought injury.

Incidentally, this experiment taught two lessons: First, that it is hazardous to allow young trees to suffer for water to the extent of slowing down their growth and, second, that certain trees, at least, do not recover after once having been injured from overcrowding during a period of dry years.

FACTORS INFLUENCING PLANTING DISTANCES

Horticultural writers have not always been uniform in their advice as to the amount of space trees should be allowed or as to their exact arrangement in the orchard. Even experienced fruit growers in a limited district may not be entirely in agreement as to how the trees should be spaced or the total number that may be allowed to the acre. There are certain basic considerations which need to be taken into account in deciding planting distances.

Even under best conditions for normal growth not all fruit trees attain the same size at maturity; moreover, growth habits of the different species and varieties as to size and shape are quite varied. Some are normally tall and slender, at least for many years, while others are spreading in their habit of growth from the beginning. Sweet cherries, for example, in good soils often attain a height of thirty-five feet and a branch spread of perhaps twenty feet; while sour cherries are rarely over twenty feet high and have a branch spread not exceeding twelve or fifteen feet. Pears are noted for being upright in their growth, while apples and apricots are generally wide-spreading. Some trees when grown on certain rootstocks such as the Bartlett pear on the quince are also, normally, dwarfs.

The soil, whether deep or shallow, has much to do with the size of a tree of a given species or variety. On shallow soil even trees that are normally large, if they survive, are apt to be small. However, on such soils where the roots are unable to penetrate deeply, they are apt to range widely in search of both food and moisture so that trees should not be unduly crowded simply because it is known that they will not attain large size.

The moisture supply in the soil is perhaps the most important single factor affecting the growth of fruit trees. Even on the most productive soils, trees will make a small growth, soon lose their vitality, and gradually die if allowed to suffer for water. Evidence of this has been noted in non-irrigated orchards, especially those where small fruits are interplanted between the trees.

Tree sizes can be regulated to a considerable degree by pruning. Heavy annual pruning consisting of shearing back the new growth tends to keep the trees small. This type of pruning may adapt them to certain planting distances, whereas if they were handled by the so-called "long pruning," they would inevitably require more space. There are really two considerations: the welfare of the roots as regards a proper moisture supply, and the welfare of the tops. If unduly

crowded, the tops may not secure the necessary amount of sunlight; moreover, harvesting, spraying, and other field operations may be hampered. Root growth, too, is influenced by heavy pruning.[2] Heavy shearing of the branches annually tends to restrict the growth of the roots.

Again, the purpose of the orchard may have an influence on the spacing of the trees. Most orchards are planted with the idea that the trees are to be permanent and hence they should be given a sufficient amount of space for the best development of both tops and roots over a long period of years. Under certain circumstances it may seem necessary to plant a temporary orchard in which the trees may be set very thickly. They are brought into bearing early and given little or no pruning in order to secure a few heavy crops; then, when their vigor begins to decline, all are removed from the land. In times of high prices for a certain fruit it may be good business to give the trees a reasonable amount of space in which to develop but yet plant the maximum number of trees to the acre. Such growers, of course, should be willing to take the risk of injuring the trees by slight crowding. The returns from the orchard may justify this procedure, although the orchards should be regarded as only semi-permanent.

A single adverse season as regards water supply may result in severe or fatal injury to a high percentage of such trees, whereas under favorable conditions of moisture and with first class cultural attention they may survive and be useful for many years.

Table 2 may be useful in computing the number of trees required for any given area.

TABLE 2

NUMBER OF TREES REQUIRED PER ACRE

Planting distances, in feet	Number of trees per acre square or alternate planting*
18 x 18	134
20 x 20	108
22 x 22	90
25 x 25	70
27 x 27	59
30 x 30	48
35 x 35	35
40 x 40	27
50 x 50	17
60 x 60	12

* Figures are exact only for a multiple of acres. For hexagonal planting add 15 per cent to above figures; for quincunx planting add 100 per cent.

[2] Chandler, W. H. Results of some experiments in pruning fruit trees. Cornell Univ. Agr. Exp. Sta. Bul. 415:5–8. 1923.

RELATION OF PLANTING DISTANCES TO THE GROWTH AND FRUITING OF THE TREES

Tree growth.—The accompanying chart, figure 1, illustrates the total size of the experimental trees on the University Farm and also the annual rate of growth as measured by increase in trunk diameter. During the first three years after planting, differences in growth between the trees planted at 12 feet and those planted at 30 or 36 feet apart are small and of no special significance. The fourth season, 1918, being unfavorable on account of only ten inches of rainfall between September, 1917, and September, 1918, and no irrigation water available, all trees made less growth than either the year previous or the one following. At this time the apricots and peaches planted at the wider distances were of decidedly larger size. During 1919 all trees made a uniform gain except the apricots which again made a relatively small amount of growth in the closely planted blocks. Beginning with 1920, another dry season, the dwarfing effects of close planting were even more apparent.[3] It will be noted that the effects of the varying distances were much more marked with the apricot, peach, and cherry than with the plum, prune, and pear. The growth for the pear is particularly uniform in each of the planting distances during the entire ten-year period.

The relative amount of space available for the development of the tree-top or spread of branches has been correspondingly striking. Peaches and apricots, naturally of a spreading habit, were by 1918 in the closer planted blocks being forced into a smaller, more upright habit of growth, as illustrated in figure 2 and figure 5A. The amount and vigor of the new wood produced also gradually became less until 1922, when, in a much weakened condition, 50 per cent of the trees were removed. Although to a somewhat lesser extent plums, prunes, and cherries were likewise influenced under similar conditions, and thinning was also necessary in order to prevent the gradual dying of the trees. Pears, naturally of an upright habit, have been the least affected in the character of their growth. Crowding has produced smaller and perhaps slightly weaker trees, but the general character of growth has been little influenced.

Fruiting habits.—As the branches of the peach and apricot when crowded were forced upward to secure sunlight, the new wood bearing all the fruit of the peach and a portion of that in the apricot became more limited and higher up in the tree. With a gradual dying of

[3] Increase in size of trees planted at 12 and 16 feet during and after 1922, primarily the result of thinning.

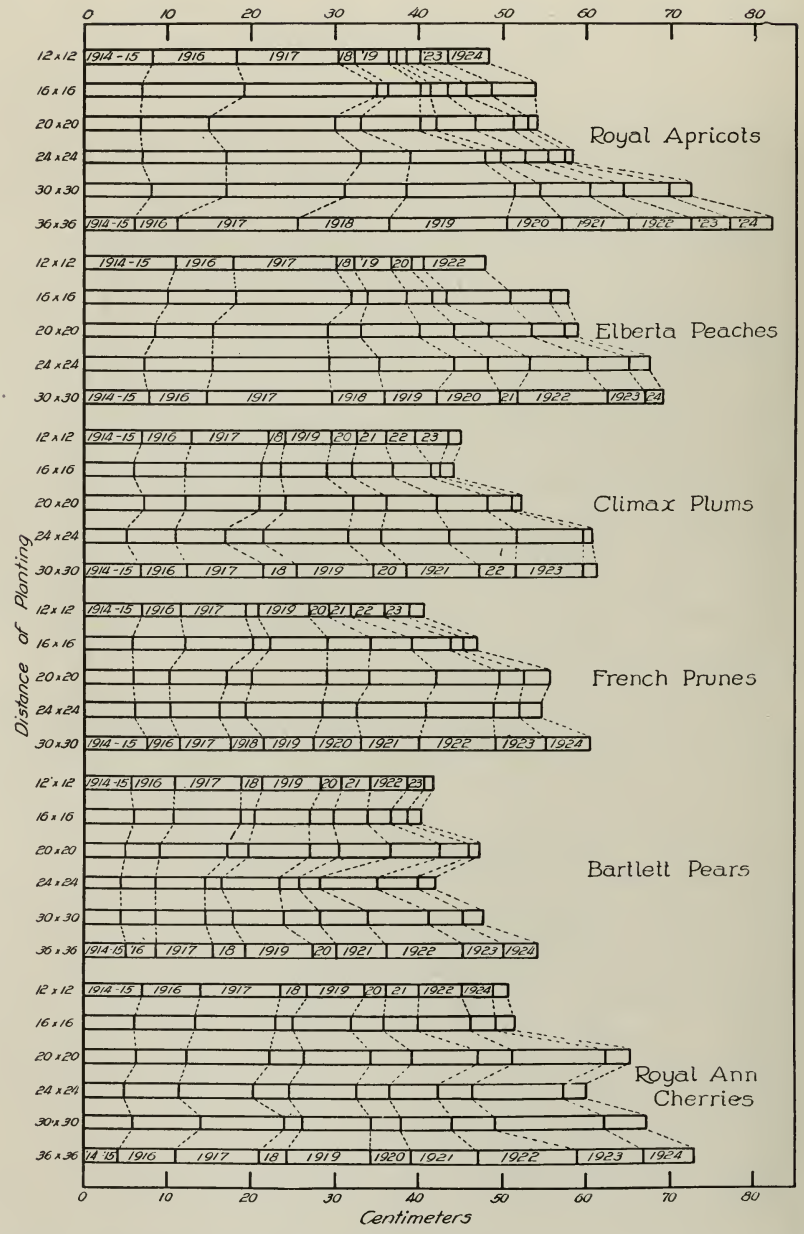


Fig. 1.—Average annual and total trunk diameter growth of trees at different planting distances.

the older bearing surface on the lower branches the subsequent crops were reduced. Trees producing their fruit primarily on spurs or having a natural, upright habit of growth, were little influenced in their fruiting habits.

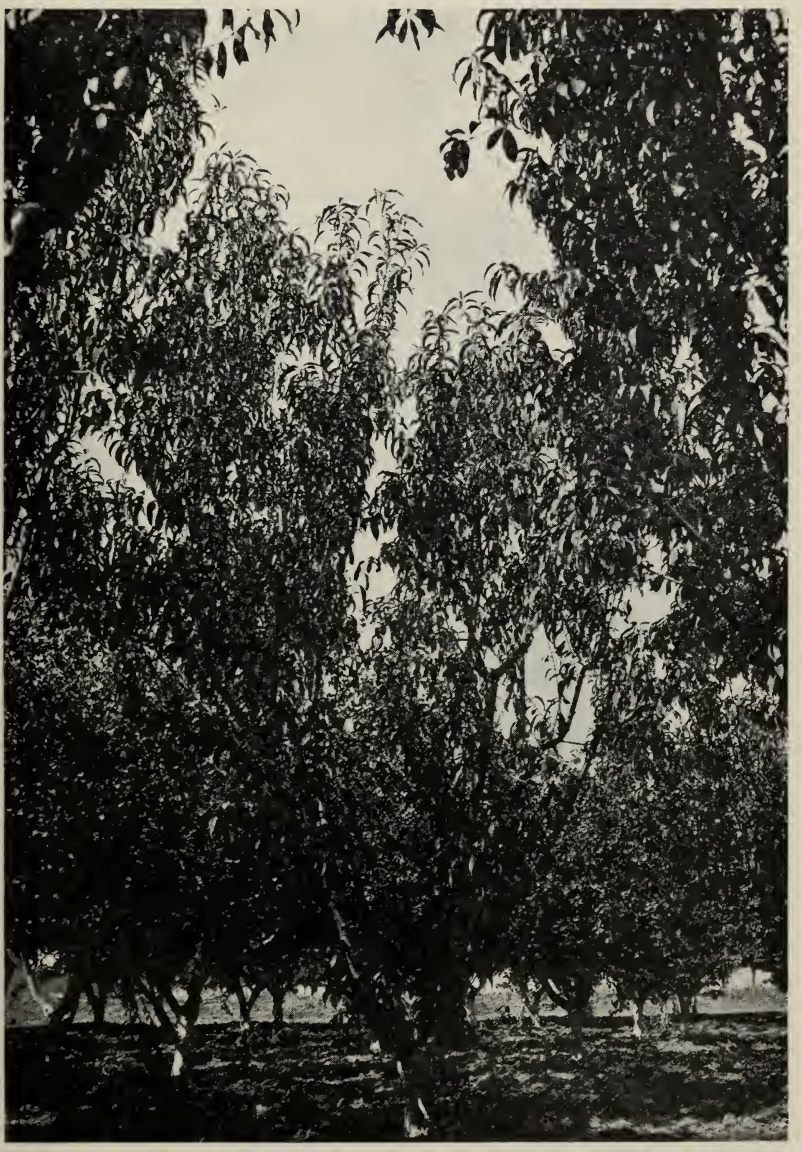


Fig. 2.—Elberta peach trees 12 x 12 feet apart. Photographed in 1922 before thinning. Very upright growth of branches with little fruiting wood except in the tops of the trees.

Yields.—Both frost and lack of adequate irrigation reduced the yields of the trees under experiment to such an extent as to make them scarcely comparable with yields in many commercial districts. However, the yields of the different plots are comparable and a few very significant facts are brought out by the records secured. Table 3 shows weights of fruit secured, while figure 3 shows the same data in diagrammatic form.

TABLE 3

FRUIT YIELDS PER ACRE—1918–1925

Trees	Planting distance, feet	Number of trees to the acre	Annual yield in pounds to the acre								Total
			1918	1919	1920	1921	1922	1923	1924	1925	
Royal apricots	12 x 12	302	322	3,865	19,751		4,432*	2,703	3,722	2,340	37,145
	16 x 16	170	119	3,196	7,922		5,333†	3,876	2,422	4,250	27,118
	20 x 20	108	.....	2,528	4,622	No	11,253	4,978	270	7,938	31,589
	24 x 24	75	.....	2,010	6,277	crop	10,237	600	1,071	10,125	30,320
	30 x 30	48	14	2,476	3,945		7,780	590	1,761	8,040	24,606
	36 x 36	33	.....	1,132	3,484		7,375	3,171	6,448	3,782	25,392
Climax plums	12 x 12	302	1,540	4,167	9,633		15,462	3,956‡	1,939	4,620	41,317
	16 x 16	170	1,360	2,176	8,959		9,775	6,120	1,054	2,397	31,841
	20 x 20	108	712	2,170	6,589	No	11,016	9,450	1,404	2,775	34,116
	24 x 24	75	52	1,012	3,915	crop	13,125	7,770	3,787	5,475	35,136
	30 x 30	48	465	681	2,313		6,081	9,168	1,636	2,001	22,345
	36 x 36	33					No trees				
Pond plums	12 x 12	302	.....	543	3,926		9,483			3,382	17,334
	16 x 16	170	.....	255	6,137		7,242			3,910	17,544
	20 x 20	108	.....	194	4,708	No	5,400	No	No	2,754	13,056
	24 x 24	75	.....	.....	727	crop	420	data	crop	3,750	4,897
	30 x 30	48	.....	105	1,752		312			4,200	6,369
	36 x 36	33					No trees				
Bartlett pears	12 x 12	302	.....	2,506	2,657		11,476	10,479	.....	33	27,151
	16 x 16	170	17	680	1,139		6,749	2,031	.....	714	11,390
	20 x 20	108	10	648	928	No	6,815	5,400	1,944	356	16,101
	24 x 24	75	.....	150	285	crop	5,310	5,332	840	3,825	15,742
	30 x 30	48	.....	62	729		7,752	8,208	3,043	3,504	23,298
	36 x 36	33	3	613	1,359		2,614	4,494	1,821	4,851	15,755
Elberta peaches	12 x 12	302	120	1,087	.....		.....	.....		1,700	2,907
	16 x 16	170	1,683	850	782		396†	.....		6,493	10,204
	20 x 20	108	21	4,978	2,581	No	7,214	.....	No	4,060	18,854
	24 x 24	75	52	4,125	10,185	crop	20,850	637	crop	14,700	50,549
	30 x 30	48	14	3,062	7,636		21,216	16,857		14,640	63,425
	36 x 36	33					No trees				
French prunes	12 x 12	302	.....	3,050	6,432		4,983	2,174‡		985	17,624
	16 x 16	170	.....	1,037	5,321		2,004	10,574		2,805	21,741
	20 x 20	108	.....	291	2,149	No	4,212	19,332	No	5,400	31,384
	24 x 24	75	.....	217	1,597	crop	1,147	14,612	crop	7,695	25,268
	30 x 30	48	.....	163	446		1,003	10,171		6,240	18,023
	36 x 36	33					No trees				

* Trees thinned from 302 to the acre to 75.5 to the acre leaving only one-fourth of the original planting.
† Trees thinned from 170 to the acre to 85 to the acre, leaving only one-half of the original planting.
‡ Trees thinned from 302 to the acre to 151.5 to the acre, leaving only one-half of the original planting.

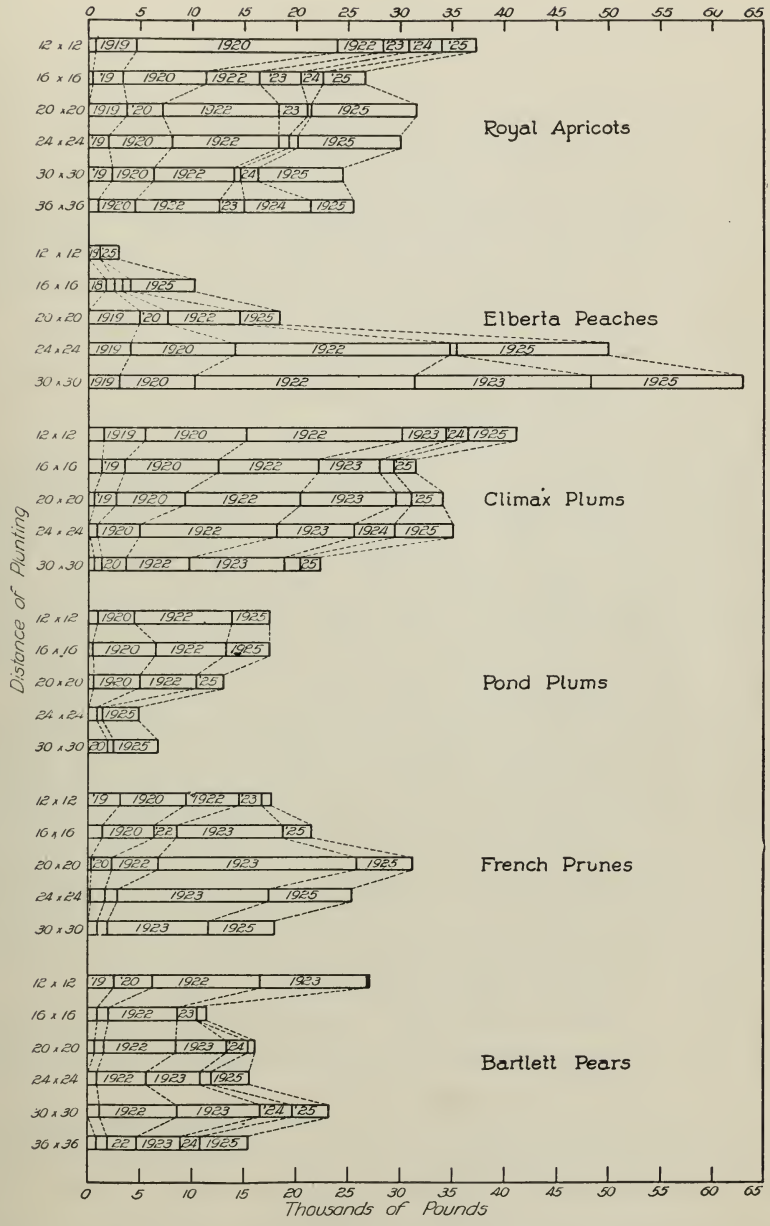


Fig. 3.—Average annual and total yields of trees per acre under different planting distances.

In the case of the peach, the growth, vigor, and fruiting habits were so early influenced by the close planting that the trees set closer than 20 feet produced practically nothing except during 1925 when only two remaining alive and no longer crowded produced a fair crop. Trees planted 24 and 30 feet apart have produced not only greater yields per tree but the largest tonnage per acre.

With the apricot the general results were similar but not so marked. A large acre yield was produced on 5-year-old trees planted 12 x 12 feet. The fruit, however, was small and of little commercial value; during the subsequent four fruiting seasons the trees planted 20 and 24 feet gave the highest yields. While it is speculative to forecast the future, there are reasons for believing that the trees standing at 30 and 36 feet will, during the next five years, produce the largest total yields per acre.

French prunes have likewise failed to give larger yields from the very closely planted trees during the first five crop years, and although the 20-foot spacing produced a crop in 1923 which to date gives this spacing the highest yield, the increase in production of the 24-foot planting during 1925 indicates that this distance will very soon become the most profitable. The 30-foot planting, while producing larger yields per tree, naturally does not make a favorable showing in total acre yields until the trees reach 15 or 20 years of age.

During the season of 1925 yield records were secured from an orchard in Napa County where one hundred 14-year-old French prune trees, growing 30 feet apart, yielded 4.9 green tons per acre as compared with 5.6 tons from a similar number of trees 30 years of age planted only 18 feet apart. In this instance where only 48 trees per acre are compared with 100 per acre, the difference in yields of dried fruit was not great and the size of the fruit in the former instance ran from 30 to 45 to the pound as compared with 50 to 60 to the pound from the closer planted trees.

Climax and Pond plums, both naturally smaller growing trees than apricots, peaches, or prunes, undoubtedly require relatively close planting in order to secure large tonnage.

The yields from the Bartlett trees under experiment were so small as to make definite conclusions unwarranted. It seems, however, that since trees planted 12 feet apart gave practically the same acre yields as those planted 30 feet apart and since they were not materially weakened by the crowding, this fruit is adapted to rather a wide range of planting distances. Observations in commercial orchards also indicate that the Bartlett is capable of adapting itself to its surround-

ings. It is believed that this conclusion holds true with the pear generally, although little information is available on any other variety.

No yields have been secured thus far from the cherries under test. Under favorable conditions, however, the sweet cherry produces a large tree and hence may be expected to give good yields under at least moderately wide planting. With unrestricted room for development, a 15-year-old tree in the orchard of Giblin Brothers of Yuba City in 1924 produced 1453 pounds of fruit as compared with an average yield of 532 pounds from trees in the orchard standing 20 x 40 feet apart.

HARMFUL EFFECTS OF CLOSE PLANTING

Mistakes which have been made in planting have been almost without exception those of planting the trees too close. In orchards planted many years ago this was a mistake very easy to make. New fruits were being planted in different sections of the state with but little definite information as to how much space the trees would occupy eventually. Many of these pioneer orchards and occasionally some planted more recently, are now recognized as having been set too close.

Interlocking of the branches between the tree rows renders cultivation and spraying difficult. At harvest time when the branches are bending under a load of fruit, picking and handling the crop in the orchard is exceedingly difficult. The crowding of branches and the large leaf area during the growing season also produce a large amount of shade which may prove detrimental by preventing proper coloring of the fruit or by actually killing off or preventing the formation of new fruit-buds and spurs. While a certain amount of sunlight is necessary in order to carry on the normal wood and leaf growth of the tree, even more is required for fruit-bud formation. This seems most striking with apricots and peaches where under conditions of limited light all of the fruiting area is found on the uppermost branches.

Yields and size of fruit may also be reduced by the severe competition of the individual trees for the moisture and mineral elements in the soil, as has been strikingly set forth by the experiments cited above.

DOUBLE PLANTING

In an effort to secure a greater income from the trees during the first few crop years, the idea of double planting is often carried out. Occasionally the trees and tree rows are planted twice as close together as they are planned to stand permanently, but more often the quincunx system of planting the permanent trees in a square with a temporary tree in the center of each is used. This method, if well planned, has promising possibilities but very grave dangers. It is believed possible, on good soil, with an unlimited water supply, and with good management, to make the temporary trees—those in the center of the square—more than pay for their care, thus giving some returns which would otherwise not be received. If at the time of setting the orchard one is undecided as to which of two fruits or varieties will make the best growth or prove the most profitable he may find double planting advantageous. Not infrequently is the final decision in this connection postponed until after the trees produce several crops, and the market demands are established.

Against these possibilities is the danger that the close planting may exert a dwarfing effect upon the trees even before they produce their first commercial crop and if allowed to remain until some paying returns can be secured, permanent damage may be done.

The details presented in figure 1, of trees planted from 12 to 36 feet apart, show how early the tree growth was checked by close planting. Figures 4 to 8, inclusive, also bring out more forcibly the comparative size and condition of the trees at the time of and subsequent to thinning. While this much weakened condition was doubtless exaggerated by an insufficient water supply, it is believed that water scarcity is also the limiting factor in many commercial orchards. Figure 9 shows just such a condition in a Napa Valley orchard, which is typical of similar orchards in many sections. So long as all the trees are standing in their crowded condition, the harmful effects of such planting is not evident. As soon as the temporary ones are removed, however, the mistake is easy to see.

As mentioned above, perhaps the primary purpose of double planting is to secure larger returns. How successfully does such a practice work out in commercial orchards? Since comparative yields are not available, the question can only be answered by giving the opinions of orchardists who have followed this system. Trees planted by H. G. Boyce, near Winters, in 1893, 24 feet apart on the square, were thinned by removing alternate diagonal rows in 1913, allowing

Fig. 4.—Eight-year-old Elberta peach trees. A, two years after thinning from 12 x 12 feet to 24 x 24 feet. Only one tree out of four of any value. B, trees planted 20 x 20 feet. Half of the trees in fair condition, others very weak. C, trees planted 24 x 24 feet. All in good condition. Compare with trees in A.

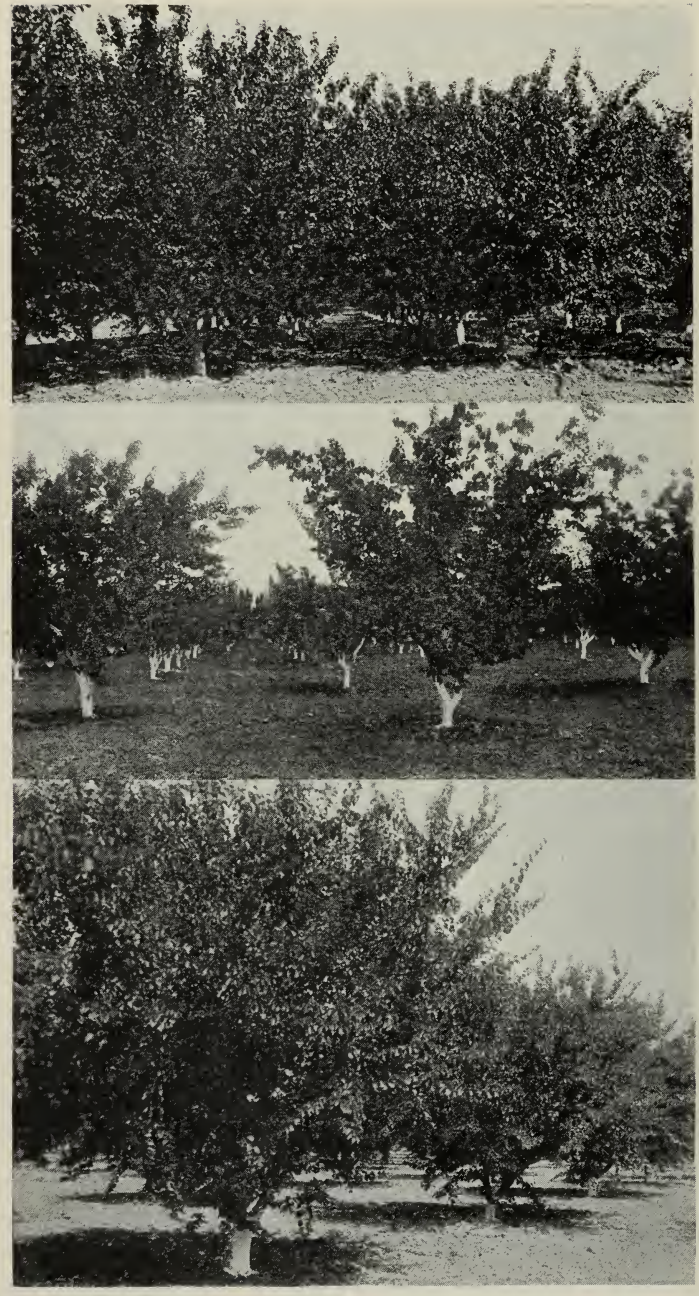


Fig. 5.—Royal apricot trees. A, trees six years old standing 12 x 12 feet apart. B, same trees second season after thinning to 24 x 24 feet. C, comparable trees planted 24 x 24 feet. Compare size and vigor.

the remaining trees to stand 48 x 48 feet on the square but only 34 feet on the diagonal. Though the branches are touching in the close or diagonal direction, the trees produce large crops. An additional 20 acres of 10-year-old almonds will in a few years be thinned in like

A

B

Fig. 6.—Eight-year-old Climax plum trees. A, trees thinned several months before photographing from 12 x 12 feet to 24 x 24 feet. B, trees originally planted 24 x 24 feet. Compare size and vigor.

manner. Mr. Boyce is of the opinion that he would in all probability plant and handle another orchard in the same way.

Mr. William D. McKenzie, an extensive grower of prunes and pears at Monticello, believes double planting to be an economic

Fig. 7.—Eight-year-old Royal Ann cherry trees. A, thinned several months previous to photographing from 12 x 12 feet to 24 x 24 feet. B, trees planted 20 x 20 feet. C, trees planted 24 x 24 feet. Note comparative size of the trees planted at 24 feet.

A

B

Fig. 8.—Eight-year-old French prune trees. A, trees thinned several months before photographing from 12 x 12 feet to 24 x 24 feet. B, trees originally planted 24 x 24 feet. Note the comparative size and vigor.

advantage. In planting French prunes, he would consider setting the trees 20 x 20 feet on the square with the idea of later removing the diagonal rows.

Mr. E. A. Gammon, pear grower at Hood, believes peaches and plums might well be planted as temporary trees between pears set 18 x 18 feet under his conditions on the bottom lands of the Sacramento River.

Fig. 9.—Twenty-year-old prune orchard interplanted with peaches. Peach trees, of which the one in the center foreground is the first of the row, are very weak, with little fruiting wood, while the prune trees in blossom on either side have not had proper chance for their best development.

Batchelor[4] states, in connection with the practice of double planting walnuts 30 x 60 feet, that "By this method properly carried out, nearly twice the tonnage may be expected during the first 10 to 14 years, as where only the permanent trees are planted." These instances are typical of the views of many orchardists.

On the other hand, there are many growers who condemn the practice on the ground that the orchard will not be thinned in time and that the extra trees will not materially increase the returns. This opinion deserves special consideration with such fruits as the peach and the plum, which make a quick growth and come into bearing early. Double planting apple orchards does not seem feasible in the leading producing districts of California because there are no suitable

[4] Batchelor, L. D. Walnut culture in California. Calif. Agr. Exp. Sta. Bul. 379:38.

commercial varieties grown which will give profitable returns before the trees begin to crowd. Moreover, such fruits as plums or peaches, which might be suitable for this purpose, are not well adapted to the apple sections.

Figure 10 shows a 14-year-old almond orchard where the trees are planted 30 x 30 feet apart quincunx system with peach fillers. Although the size of the trees has been reduced somewhat by crowding, good care and plenty of water have up to this time maintained sufficient

Fig. 10.—Almond orchard with peach fillers. Almond trees 30 x 30 feet with peach trees in the center.

vigor to make them profitable. Just how much longer they can continue to produce their present returns under such conditions is, however, difficult to state.

The advisability and profitableness of the practice of double planting, therefore, depends primarily upon the kinds of fruit grown, the difference in time required for the permanent and temporary trees to reach good bearing age, the available water supply, and last, but perhaps most important of all, the courage of the grower to remove the temporary trees at the proper time.

Thinning old orchards.—As mentioned previously, many of the older orchards, planted with little knowledge of how the trees would grow and at a time when very severe pruning was generally practiced, are now badly crowded. Even with severe heading of the main limbs, often into two- and three-year-old wood, cultivation and spray-

ing has become difficult, and with the branches weighted down under a load of fruit, harvesting is much more of a task. How should such orchards be treated? Should they be allowed to remain as they are with the inconveniences and with the extra expense of handling, or should part of the trees be removed? The answer to these questions depends almost entirely upon the individual orchard and upon the orchardist. In some cases, thinning would be recommended without hesitation. In others it would be considered a mistake, particularly where thinning has been delayed until all the trees are permanently injured. With the peaches and apricots planted 12 x 12 feet apart on the University Farm, permanent injury occurred before any of the trees were removed, although to have thinned the trees much sooner would have meant removing them before any returns had been received.

Figure, 1, showing the growth of apricots, peaches, and plums, discloses a slight gain in tree size in the plantings during the seasons of 1922 and 1923, but figures 6, 7, and 8 show that the trees were dwarfed, and in the case of the peach trees, were almost killed before thinning. A similar condition was observed in an old apple orchard in Sonoma County where the trees, long standing 20 x 20 feet, had been thinned several years previously to 40 x 40 feet. These trees, receiving only the natural rainfall, had competed with each other for soil moisture so long as to make any material increase in growth after thinning very doubtful. Moreover, 75 per cent of the trees had been removed so as to make a commercial crop practically impossible.

The great majority of mistakes, however, have been those of not thinning; a few specific instances of successful thinning are listed in table 4.

In numerous instances in Orange County, very marked increases in walnut yields have been secured the third or fourth year after the removal of half the trees originally planted 40 feet apart.

In considering the time and method of thinning, the system and distance of planting, severity of crowding, kind and age of trees, type of soil, and method of pruning should all be taken into consideration. The system and distance of planting determine the spacing and number of trees allowed to remain. While thinning to some extent may be done by removing only a few miscellaneous trees, even distribution can be secured only by taking out from 50 to 75 per cent of the original planting through the removal of alternate rows in one or both directions, either on the square or diagonal. The summary and diagrams in table 5 illustrate the different methods and the result of each.

TABLE 4

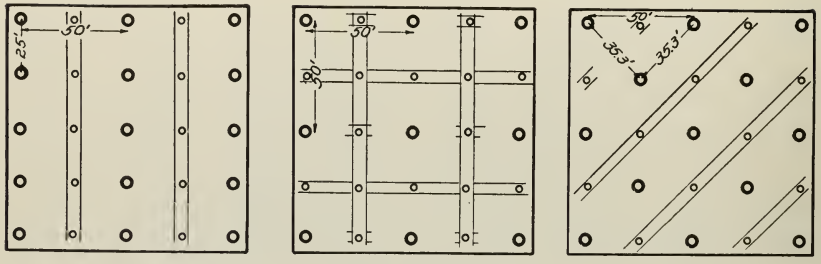
RESULTS OF ORCHARD THINNING

Orchard	Fruit	Planted		Thinned		Results
		When	How	When	How	
E. A. Gammon, Hood	Pears	1890	16 x 16	1915	22.5 x 32	Better trees and fruit and larger yields.
Wm. McKenzie, Monticello	Prunes	1890	20 x 20	1917	28 x 28	Larger and better fruit and greater yields.
Henry Wheatley, Napa	Prunes	1900	18 x 18	1915	18 x 36	Much larger trees. Comparative yields, thinned and unthinned trees, 1925, the same, but more fruit of good size on thinned trees.
H. G. Boyce, Winters	Apricots	1893	24 x 24	1913	34 x 48	Trees using all the 34-foot space. Large crops.
H. G. Boyce, Winters	Almonds	1883	24 x 24	1913	34 x 48	Large crops.
W. D. Wilkins, Mountain View.	Apricots	1898	22 x 22	1910	22 x 44	Large trees with heavy yields.
Limoneira Ranch, Santa Paula.	Walnuts	1891	40 x 40	1916	40 x 80	No increase in yields for several years previous to thinning. Yields now doubled.

TABLE 5

SYSTEMS OF THINNING

System of planting	Method of thinning	Reduction in number of trees	Form of planting after thinning	Remarks
Square	Alternate rows	50%	Rectangular	Relieves crowding only in one direction.
	Alternate rows both directions.	75%	Square	Usually too severe. Too few trees left.
	Alternate diagonal rows or alternate trees in each row.	50%	Quincunx	Most common method. Remaining trees well spaced.
Rectangular	Alternate rows	50%	Square	Trees quickly crowd in one direction.
Quincunx	Alternate rows or removal of tree in center of square.	50%	Square	Best method with double planting to secure even distribution.
Hexagonal	Alternate trees in alternate rows or tree in center of hexagon.	25%	Hexagonal	Thinning too light to be of great value.
Hexagonal or triangular.	Alternate tree in each row or alternate diagonal rows.	50%	Irregular diagonal.	Relieves crowding only in one direction.
	Alternate rows either on the square or diagonal and alternate tree in remaining row.	75%	Square or triangular.	Very satisfactory with large, thrifty, long-lived trees which will satisfactorily utilize the space. With smaller, weaker trees, the thinning is too severe.

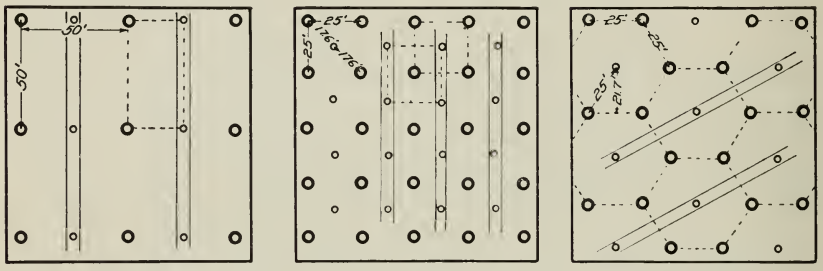


Square Planting

(A) Removal of alternate rows.

(B) Removal of alternate rows in both directions.

(C) Removal of alternate diagonal rows.

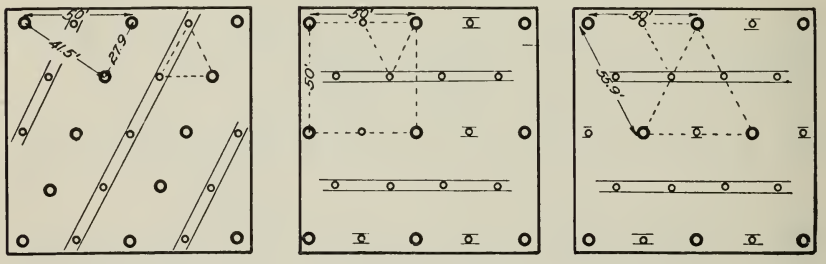


Rectangular *Quincunx* *Hexagonal*

(D) Removal of alternate rows.

(E) Removal of alternate rows or the center tree of each square.

(F) Removal of alternate rows in either of two directions.



Triangular

(G) Removal of alternate diagonal rows.

(H) Removal of alternate rows and each even tree in the remaining rows.

(I) Removal of alternate rows and each odd tree in the remaining rows.

Fig. 11.—Systems of planting and methods of thinning.

In figure 11 a uniform distance of 25 feet has been used as illustrative of the fact that although the systems of thinning have considerable similarity, they differ in the amount of space allowed each tree. Since it is often desirable to know the diagonal spacing between trees planted at different distances and according to the different systems, a few of these distances have been calculated. They are shown in table 6.

TABLE 6

Diagonal Distances Between Trees

Distances of planting (1)	Distances on the diagonal			
	Square planting (2)	Alternate planting (3)	Quincunx planting (4)	Hexagonal planting (5)
18 x 18	25.5	20.1		
20 x 20	28.3	22.4		
22 x 22	31.1	24.6		
25 x 25	35.3	27.9		
27 x 27	38.2	30.2	One-half the distances given	All trees equidistant. Same as
30 x 30	42.5	33.5	in column 2.	column 1.
35 x 35	49.5	39.1		
40 x 40	56.6	44.8		
50 x 50	70.7	55.9		
60 x 60	84.9	67.1		

Where one has a choice of two methods, the one best adapted to the trees' needs should be chosen. If crowding and severe pruning has been necessary to keep the trees within bounds, the wider spacing should be chosen. If, on the other hand, the trees are on thin soil, have never been very vigorous, and have attained practically their full size, thinning should be done lightly. It is in this connection that the orchardist must rely upon his good judgment as to how many trees should be removed. An effort must be made to forecast the probable response of the trees to the thinning. As a rule this is not extremely difficult when the factors influencing the growth of the trees are considered. Vigorously growing trees with branches interlacing clearly need more room for their development. Mature or old bearing trees making little new wood growth each year may or may not respond to a wider spacing, depending upon the factors mentioned above. While such trees may have had their vigor checked by crowding, beneficial results from thinning can probably be secured only by encouraging more wood growth through a heavier pruning, an increased soil moisture supply, or perhaps by the addition of organic or nitrogenous fertilizers. In other words, crowding has been only one factor limiting their growth, and if better orchard management generally does not accompany thinning, removing a portion of the trees will only result in loss. While old trees may be rejuvenated after thinning, much better results can be expected by removing the crowding trees as soon as it is evident that such a condition exists. As pointed out in connection with double planting, thinning is usually delayed too long. For best results, it must be done before and not after the trees become weakened. This means that the grower must

have courage to cut out approximately half of his trees just at the time when they are in prime condition. Such a practice cannot but result in a financial loss for two or three years, but where thinning is justifiable, it will likewise result in a larger crop of better fruit during the future life of the orchard. It is to be decided, therefore, whether it is more desirable to secure the maximum returns over a relatively few years or have the yields gradually increase over a long period of time. In order to permit the removal of bearing trees with the least financial sacrifice, it is suggested that severe pruning be practiced on the trees which are to be removed for two or three seasons previous to thinning. This would allow for some crop returns and at the same time would permit expansion of the trees which are to remain. It should be pointed out in this connection, however, that the roots of the trees are still competing with each other for the moisture and plant food materials in the soil, and that unless these are present in large amounts, the yields will not be as good as when the entire tree is removed. Such a practice is only a temporary expedient.

SUGGESTIONS FOR NEW PLANTINGS

It should be evident that definite planting distances can be intelligently determined only by the individual grower who takes into consideration his soil, the habits of the fruit or variety in question, and the proposed method of handling his trees. However, the following suggestions, based upon results of the above experiments and the experience of the most successful growers, are offered as being of possible assistance to prospective planters.

Almonds.—An extensive survey of the almond industry of the state by Mr. M. N. Wood of the United States Department of Agriculture reveals the fact that planting distances vary from 16 to 35 feet, the majority of trees being set at an intermediate distance of approximately 25 feet. Few new orchards can be found where the trees are planted closer than 24 to 26 feet, and on the better types of soils where the trees are to have good care, and sufficient irrigation facilities, 30 feet is recommended. Exceptionally large individual trees have been found, one near Chico having a spread of branches of forty-seven feet.

Apples.—Thirty by thirty feet has long been more or less of a standard planting distance in many apple sections of the United States. The majority of plantings in California, however, have been somewhat closer, although extreme crowding of the apple has not been so prevalent as has been the case with the other deciduous fruits.

In most of the earlier plantings in the Watsonville district the trees were set 24 to 26 feet apart, while in the Sebastopol district most of the plantings are from 20 to 24 feet. These distances, especially for the leading variety, the Gravenstein, have proved too close.

Except for small upright growing varieties, such as Rome Beauty, it is generally undesirable that the trees be planted closer than 30 feet apart. On the other hand, many varieties on good soil and under favorable conditions will easily utilize 35 feet with advantage. Particularly is this true in coastal sections subject to fog where the trees and ripening fruit should be allowed the maximum sunlight obtainable.

Apricots.—While many apricot orchards in the leading districts are planted with the trees at a distance of from 20 to 22 feet apart, newer plantings are made at a distance from 24 feet as a minimum to 35 feet as a maximum. On deep soil with plenty of water, 26 to 30 feet is recommended. The apricot generally is one of the larger growing fruit trees, and with a moderate system of pruning, most varieties, particularly the Moorpark, should be given plenty of room for development.

Cherries.—Although sweet cherry trees are characterized by an upright habit of growth, they also attain large size under ideal conditions. Twenty-four feet is suggested as a minimum distance with from 26 to 30 feet as an optimum distance on fertile, moist, but well drained soils. As mentioned previously, individual trees have been noted in Sutter County which occupied 35 to 40 feet to advantage.

Peaches.—Distances for planting peaches vary widely. In the peach sections of Placer County where many of the orchards are on comparatively shallow or thin soil, most of the present plantings are either 16 or 18 feet, and until more growth can be secured by additional water, fertility, or other means, it is doubtful if a distance greater than 20 feet is justifiable.

In the producing sections of the San Joaquin and Sacramento valleys, many orchards, including the high yielding Brandstadt Orchard at Yuba City, are planted 20 feet apart. This distance, however, is believed even by the growers of that section to be too close for continued high yields. From 22 to 24 feet is regarded as more desirable. In many of the newer orchards now being planted, 24 feet is considered a minimum. Twenty-four to thirty feet is suggested by one of the leading nurserymen, and from the results of the experiments reported in this bulletin, the greater distance may frequently be used with advantage, even though bearing peach trees should be given a somewhat more severe pruning than the other deciduous fruits.

Pears.—The pear tree seems peculiarly able to adapt itself to its environment. As pointed out, the trees in the experimental plots on the University Farm have maintained practically a healthy condition and fair vigor under the very close planting of 12 x 12 feet. Other trees in the same plots and also in other orchards have utilized a 30-foot spacing. Recommendations of from 25 to 30 feet are now quite common, but since moderate crowding at least does not seem detrimental, the 25-foot planting as a general maximum seems best for Bartletts. The majority of bearing orchards at present were planted between 20 and 24 feet. The trees are not large but do well at this distance. Pears in the Sierra foothills should naturally be planted closer than in the valley or river sections.

Plums and prunes.—Since most varieties of shipping plums are of Japanese origin or hybrids of Prunus salicina stock, few make large trees, perhaps partly because of the inherent nature of the variety itself and partly because some of the leading plum sections do not have the deepest or most fertile soil. Eighteen to 20 feet is the distance usually accepted for planting in most districts. Some plantings in the Sierra foothills are as close as 16 feet, while the experiments under soil conditions at Davis indicate that 22 to 24 feet should be the minimum.

The European or domestica type of plums, to which the prunes belong, produces a tree of considerably greater size and for the most part is grown commercially in sections favorable for good tree development. While a number of the older French prune orchards, particularly in Napa and Santa Clara Counties, were planted 18 and 20 feet apart, this distance can now be recommended only for very thin or poor soils. Some of the newer plantings are being set as far as 30 feet. Between these extremes, 22 to 26 feet is the most common average. On deep fertile soils 25 feet is suggested as a minimum distance.

Walnuts.—Following the very beneficial results of the walnut growers of Orange County in thinning their groves, 60 feet is the distance most frequently recommended at which trees should stand after about 10 to 12 years. The majority, however, favor double planting either 30 x 60 or 60 x 60 quincunx system and removing the surplus trees when they begin to crowd.

In some of the non-irrigated sections of northern California where the trees do not attain such large size, 45 to 50 feet is felt to be the most profitable distance for the permanent trees. Almonds or peaches are frequently used as fillers during the first eight or ten years of the life of the orchard.

SUMMARY

Close planting for the fruit or variety concerned is recommended (*a*) where the trees naturally fail to attain large size; (*b*) where small trees are desired and heavy pruning is practiced annually; and (c) where it is the desire to secure the greatest returns from the orchard during the first few crop years rather than the maximum average returns over a considerably longer period.

Close planting with the idea of thinning out a portion of the trees is aptly summed up by one grower who states, "All is well with close planting, if the trees are thinned before the branches and root systems begin to compete for space, but observation tells you most growers delay this far too long."

The desirability of relatively wide planting is becoming more clearly recognized with almost all deciduous fruits grown under favorable soil and moisture conditions and under a moderate system of pruning. While something is sacrificed in the size of the first few crops, the yields tend to increase steadily, the orchard continues to produce better quality and more consistent yields over a greater length of time.

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